CARA: Collision-Aware Rate Adaptation for IEEE 802.11 WLANs

Presented by

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Outline

- Introduction
- Related Work
- Preliminaries
- CARA
- Performance Evaluation
- Conclusion and Future Work

Basic CSMA/CA

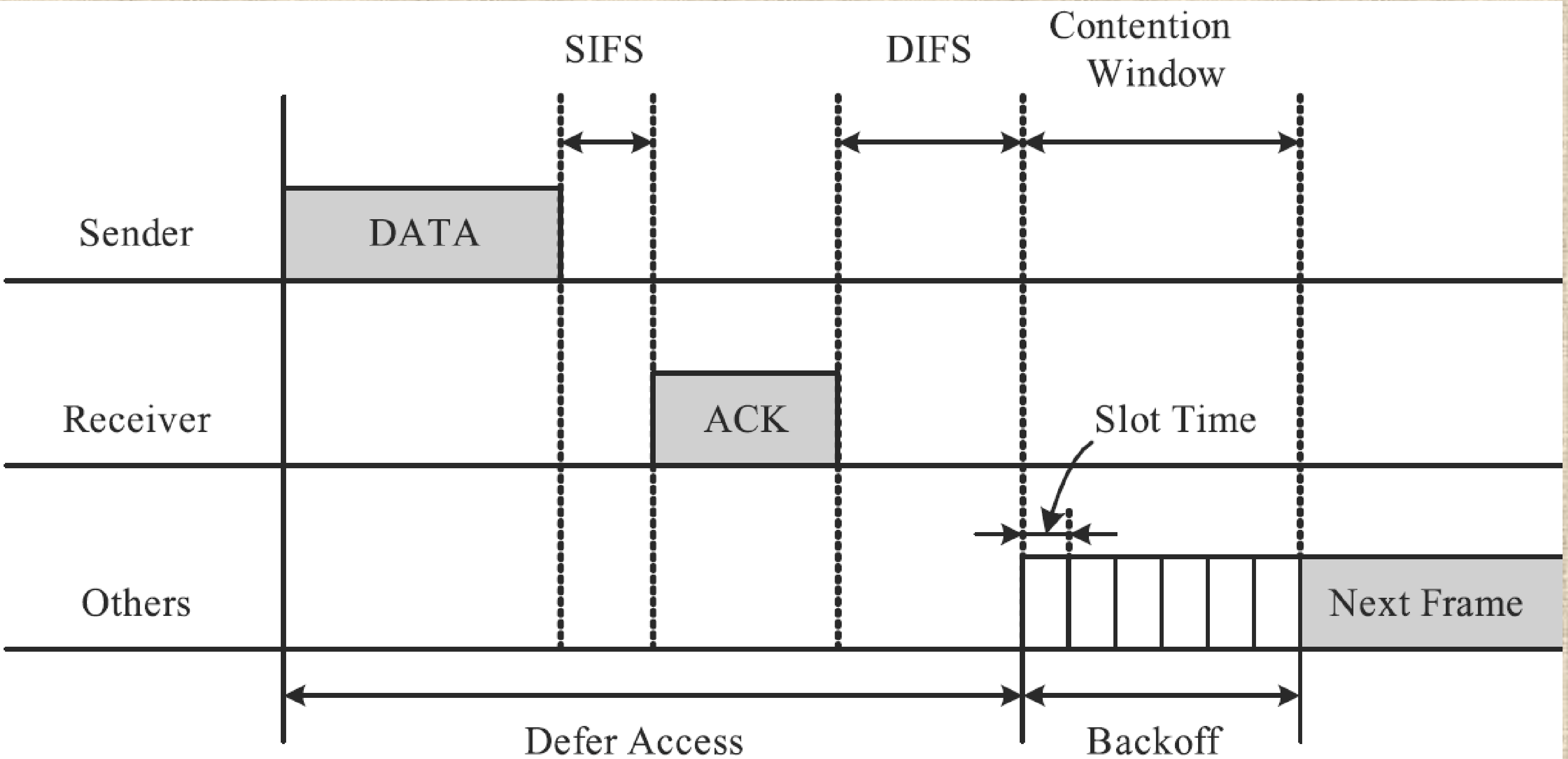

Fig. 1 CSMA/CA protocol of IEEE 802.11 MAC DCF.

Introduction

- 802.11 no rate adaption scheme
- Most open-loop adaption schemes don’t consider collision
  - Malfunction when collisions happen
- CARA
  - Combines RTS/CTS exchange with CCA
  - Collision vs. channel errors
  - No change to current 802.11 standard

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Related Work

- Rate adaption scheme classifications:
  - Closed-loop
    - Receiver feedback of desired rate by RTS/CTS
    - Transmitter adapts rate accordingly
    - Costly! Waste of bandwidth.
  - Open-loop
    - Further classified into two categories

Open-loop rate adaption

- Subcategory 1
  - Decides transmission rate by local channel est.
    - eg. ACK frame receptions
    - Usually good performance as closed-loop
    - Extra implementation efforts.
- Subcategory 2
  - Make use of local ACK information.
    - Simple implementation

Rate adaption Scheme issues

- When to increase
  - Transmitter adaptively changes rate over time
- When to decrease
  - Open-loop scheme malfunctions during collision
  - No differentiate between collision and channel errors
  - Thus, decrease over-aggressively.

Preliminaries

- CSMA/CA
  - DCF, PCF
  - CCA
- RTS/CTS exchange
  - Useful in highly-contending WLAN
- ARF
  - Timing function and missing ACK frame
- CARA

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CARA

- Adopts two methods to differentiate collisions from channel errors:
  - RTS probing (mandatory)
  - CCA detection (optional)

Identifying collision via RTS probing

- RTS probing is mandatory
  - Assume transmission error negligible
    - Small size, robust transmission rate
    - Failure of RTS transmission indicates collision
  - After RTS/CTS exchange
    - Data transmission error caused by channel errors
    - No misinterpretation
    - Overhead of adding RTS/CTS is large
  - RTS probing: enables RTS/CTS exchange only when transmission failure of data frames happens

State Transition Diagram

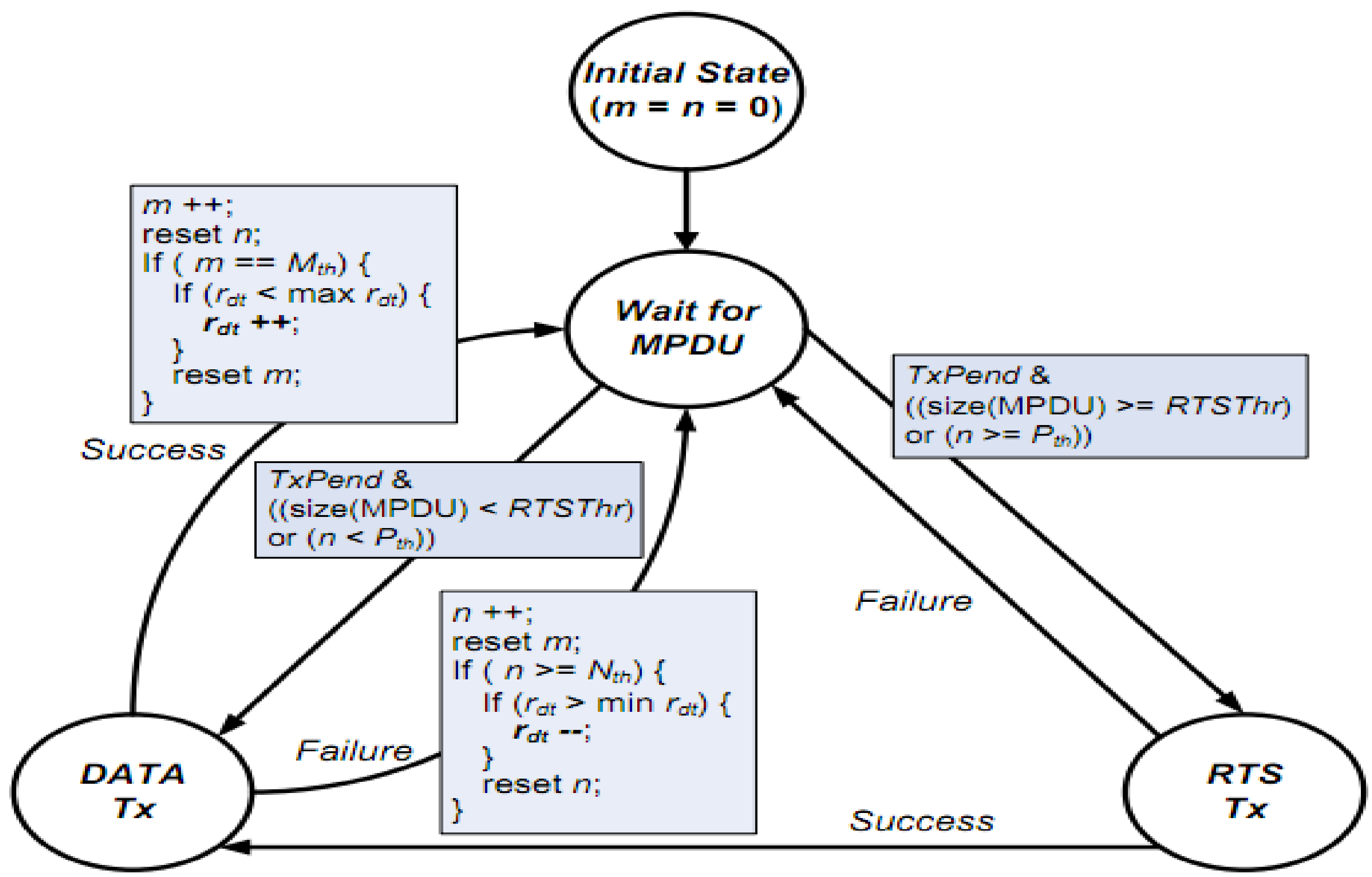


Fig. 3. State transition diagram of RTS Probing

State Transition Diagram

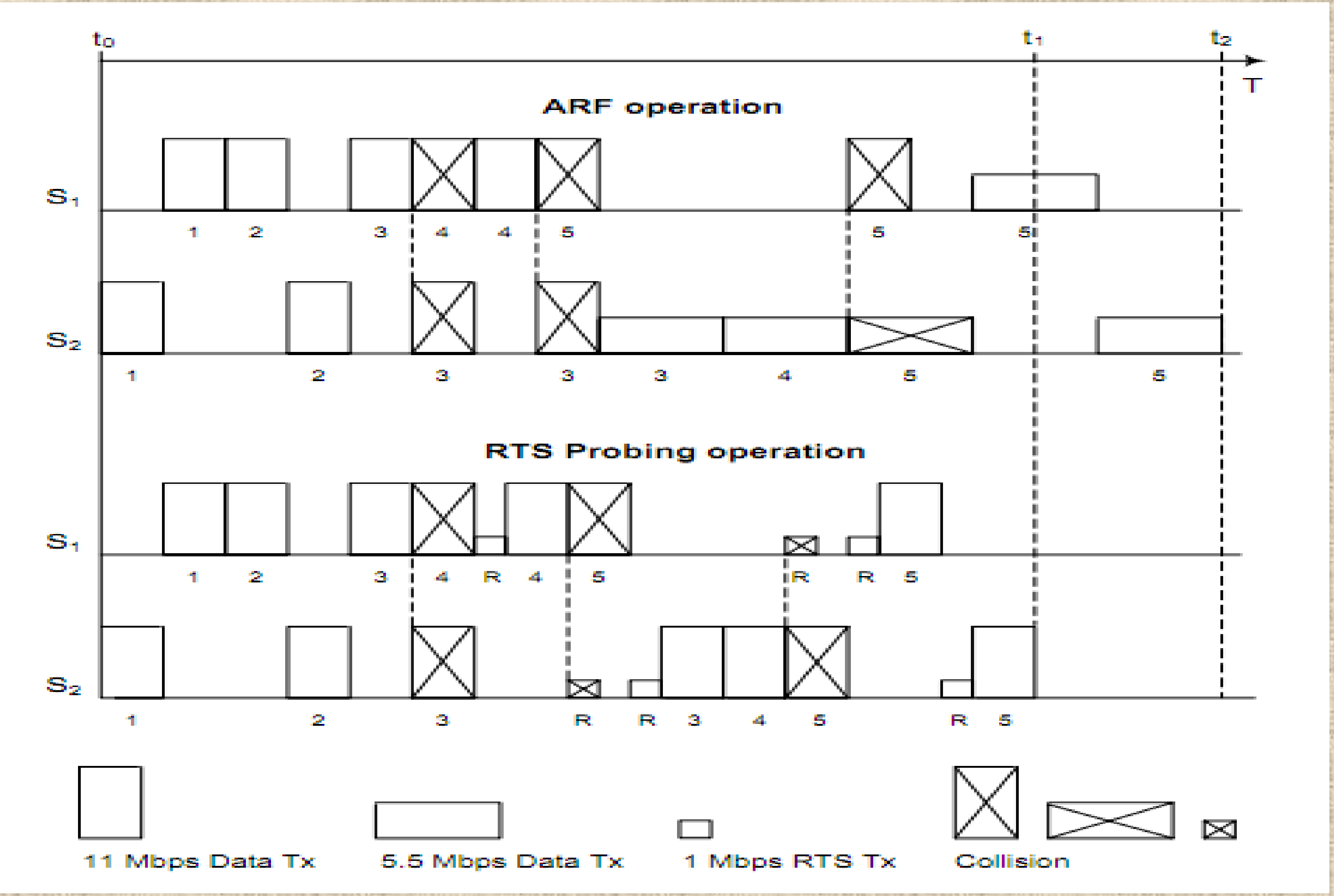
Notations	Comments
m	consecutive success count
n	consecutive failure count
M_{th}	consecutive success threshold
N_{th}	consecutive failure threshold
$TxPend$	status: a data frame is pending
R_{dt}	array of transmission rates 802.11a = $\{6, 12, 18, 24, 36, 48, 54 \text{ Mbps}\}^*$ 802.11b = $\{1, 2, 5.5, 11 \text{ Mbps}\}$
r_{dt}	transmission rate: an element of R_{dt}
$++$	increase transmission rate to the next higher one
$--$	decrease transmission rate to the next lower one
P_{th}	probe activation threshold
$RTSThr$	frame size-based RTS Threshold as defined in the standard

* The 9 Mbps rate is excluded as it is shown useless in [19].

RTS probing mechanism

- Data frame transmitted without RTS/CTS
- If transmission failed, activate RTS/CTS exchange for next transmission. If retransmission failed, lower transmission rate
- If transmission successful, stays at same rate and send next data frame without RTS/CTS

ARF vs. RTS probing



Identifying Collision via CCA Detection

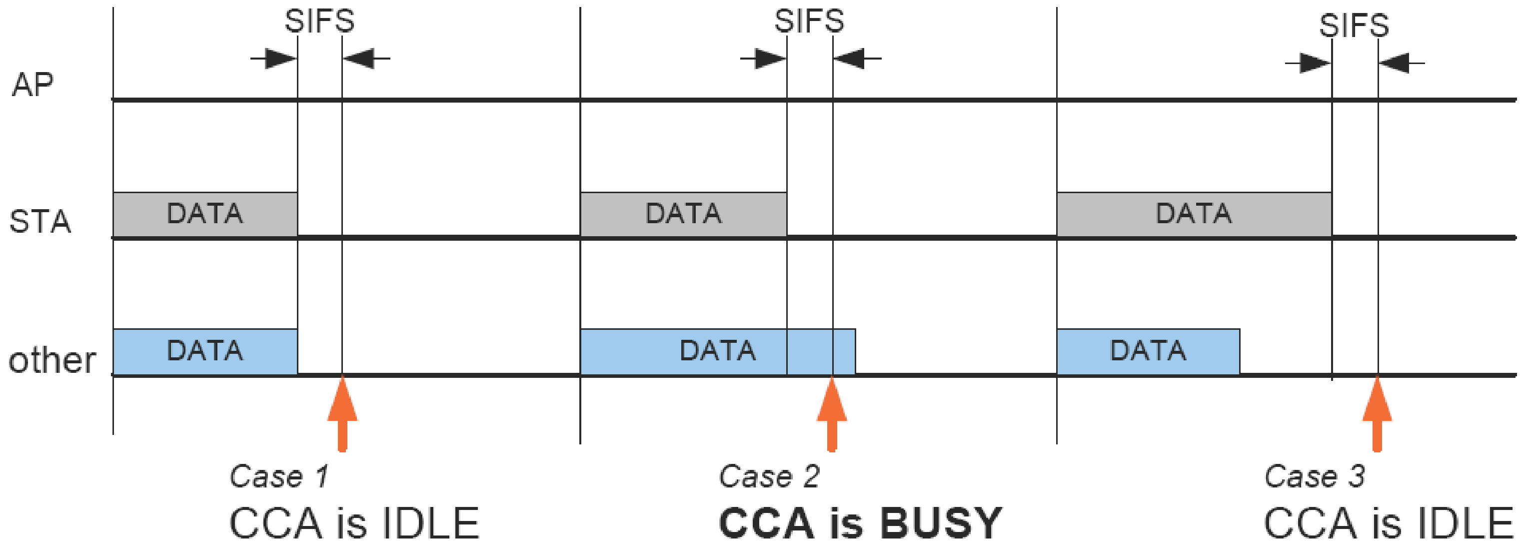


Fig. 5. Three possible cases of collision. In the second case, the collision can be detected via CCA detection.

CCA detection

- Case 1 & 3: CCA not helping
  - Because CCA cannot be sure whether collision happened
  - RTS Probing is launched later.
- Case 2: CCA helping
  - no need to activate RTS/CTS exchange.
  - Collision detected!
  - Retransmit the data.

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ns-2 simulation details

- 20dBm transmit power
- Static stations; 1500 octet MAC payload
- BER vs SNR curves measured in AWGN (Additive White Gaussian Noise) environment without fading.
- Set background noise to -96dBm
- Simulate indoor settings
- Use Ricean fading model for multi-path fading time-varying wireless conditions.

Results for One-to-One topology

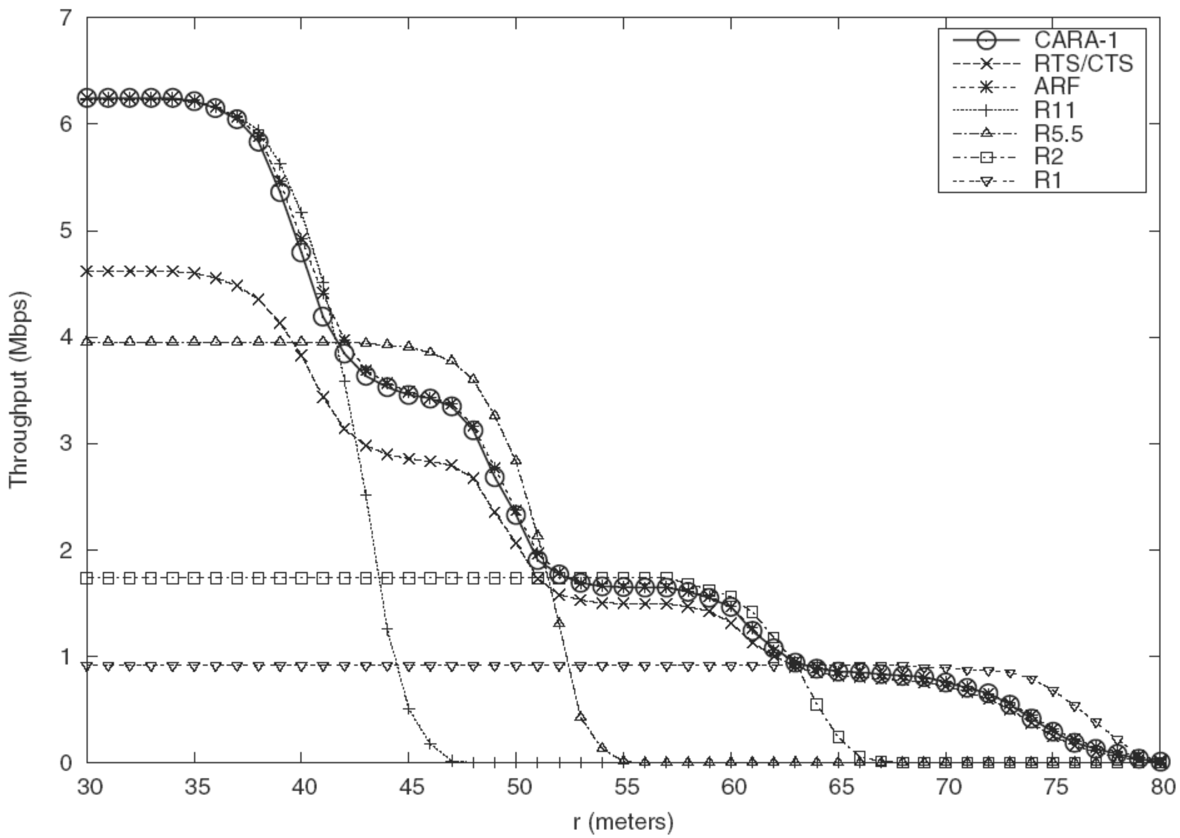


Fig. 6. Throughput comparison of our proposed rate adaptation scheme (CARA-1) against RTS/CTS, ARF, and single-rate schemes for one-to-one topology networks with various distance (r)

One station continuously transmitting to another.

X :Physical distance (meters)
Y :Throughput (Mbps)

Results for Star Topology with varing number of contending stations

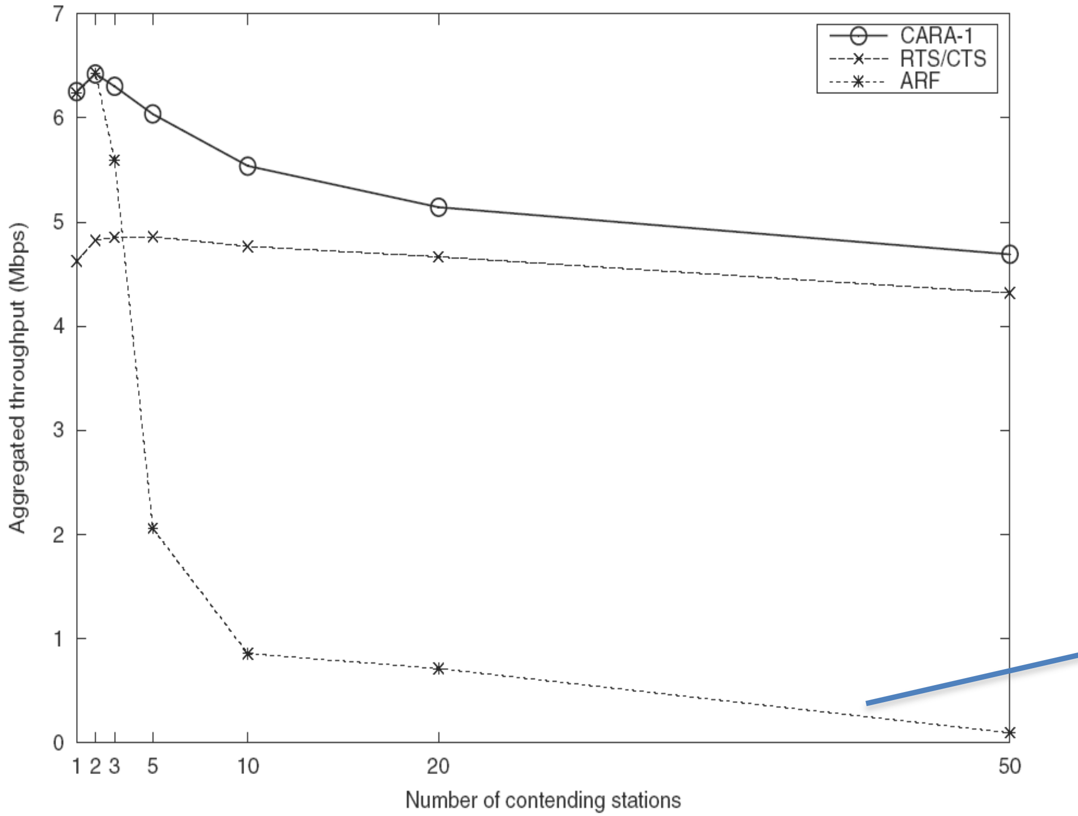


Fig. 7. Throughput comparison of our proposed rate adaptation scheme (CARA-1) against RTS/CTS and ARF for star-topology networks with various number of contending stations

Various number of contending stations are evenly placed on a circle around AP within 10 meters.

Two reasons for ARF ill behavior:

(1) Collision vs. channel errors
(2) Performance anomaly

Results for Line Topology with random data frame sizes and random station positions

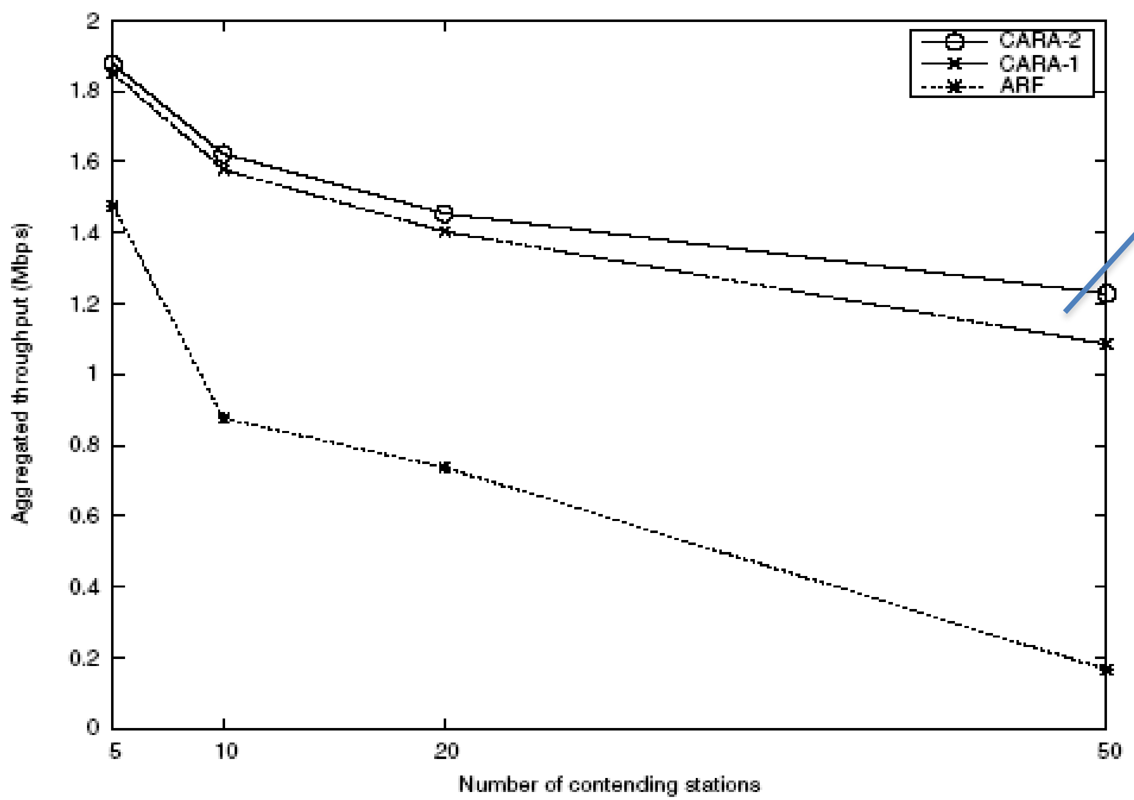
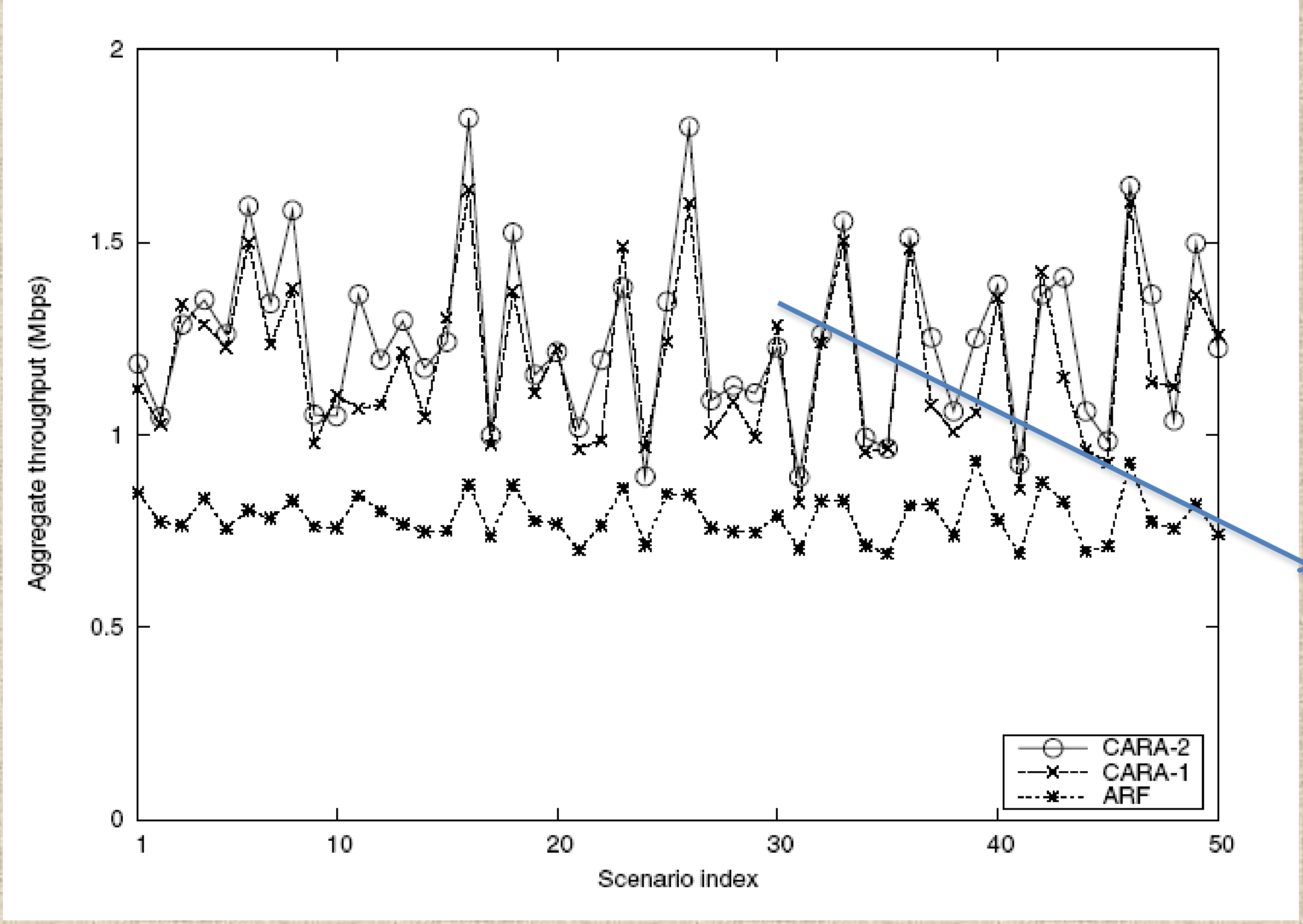


Fig. 8. Throughput comparison of our proposed rate adaptation schemes (CARA-1 and CARA-2) against ARF for line-topology networks with various number of contending stations with randomly chosen data frame sizes and stations' positions

Performance gap becomes larger: CCA becomes more helpful.

Results for random topologies with time-varying wireless channel

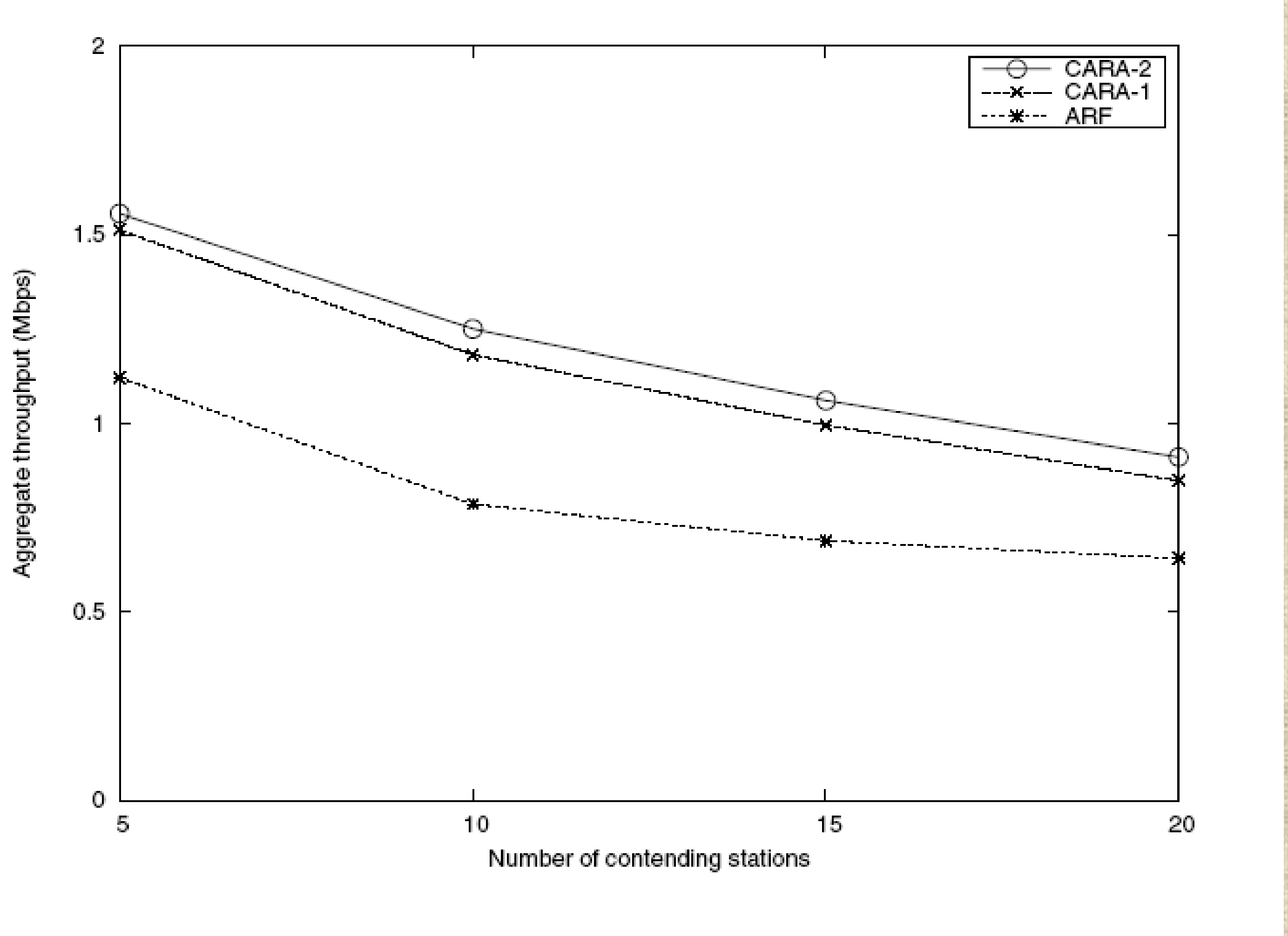


50 different scenarios
When 10 stations contend

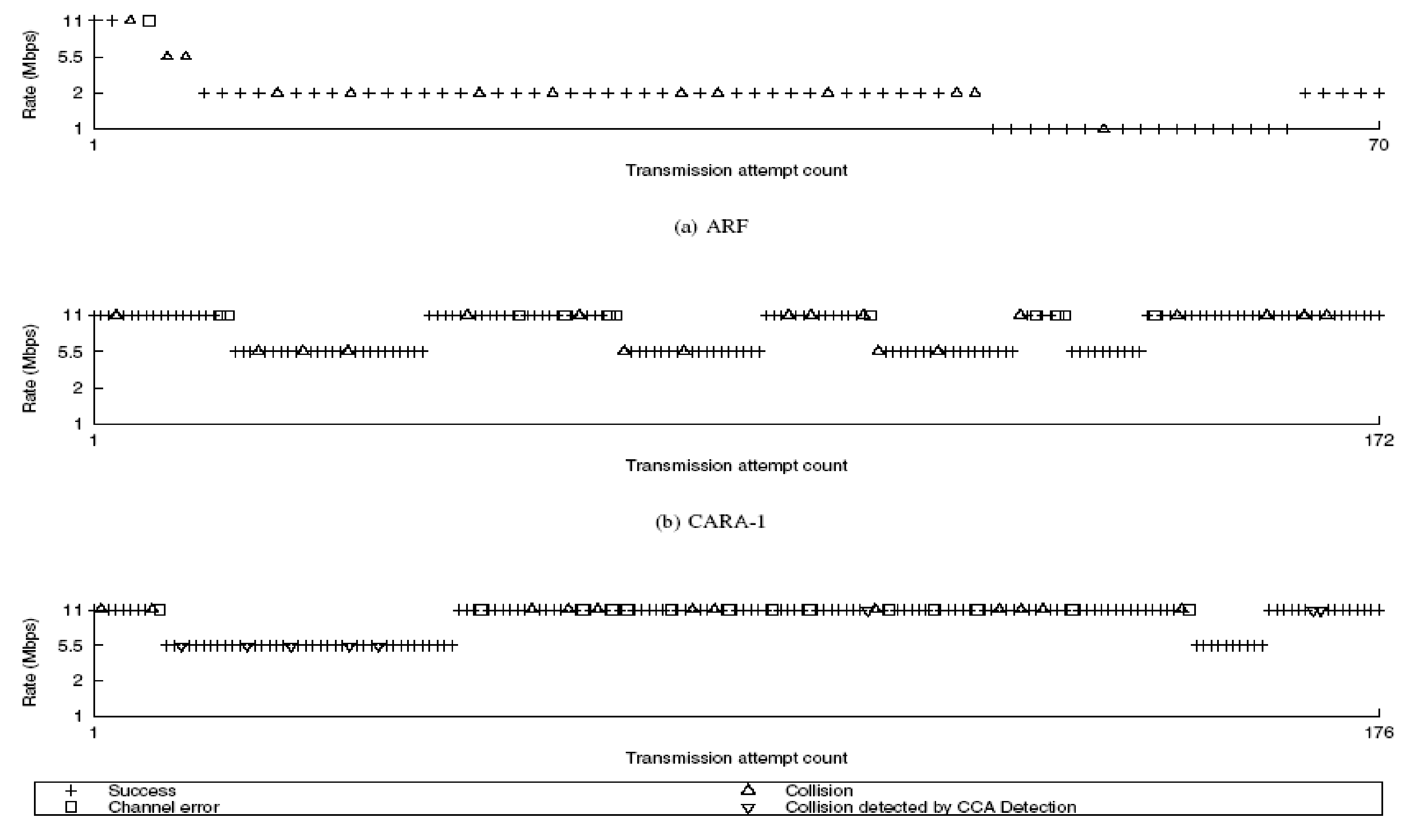
Random locations
Random data size

CARA 1 > CARA 2 ?
CCA succeeds but failed to transmit data, delaying adaptation.

Averaged result with various contending stations



Results for random topologies with time-varying wireless channel



(c) CARA-2

Transmission rate adaptation over time

TABLE II

COMPARISON OF THREE TESTING SCHEMES FOR THE 30-SECOND SIMULATION RUN

	ARF	CARA-1	CARA-2
# of tx attempts	1344	3092	3246
# of tx successes	1094	2518	2643
Throughput (Mbps)	1.58	3.37	3.49

Summary

- RTS probing is very efficient in differentiating collisions from channel errors.
  - Why CARA outperforms ARF
- CARA-2 with CCA detection outperforms CARA-1 when data transmission durations are different among contending stations.
- Collision aware rate adaptation scheme are needed due to bad performance of ARF.

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Conclusion

- CARA is more likely to make correct rate adaptation decisions than ARF.
- CARA requires no change to the 802.11 standard (unlike RBAR).
- CARA significantly outperforms ARF in all simulated multiple contending environments.

Future work

- Look at changes to the increase rate algorithm [CARA-RI].
- Study optimization of operational CARA parameters.
- Address possibility of hidden terminal detection [CARA-HD].
- Built a working CARA prototype using MadWIFI driver.